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Technical note

Mechanical properties and damage analysis of jute/polypropylene hybrid nonwoven geotextiles

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ABSTRACT

Hybrid needlepunched nonwoven geotextiles are prepared in defined weight proportions of jute and polypropylene fibres. Subsequently, a comparison is made between various physical and mechanical properties of hybrid needlepunched nonwoven geotextiles. It was found that 40 wt.% jute was an optimum level in hybrid nonwoven geotextiles that had a comparable tensile strength and higher secant modulus specifically in the cross-machine (preferential) direction in comparison to 100% polypropylene based nonwoven geotextiles. Two types of mechanical damage (i.e., a horizontal cut and a circular hole) were artificially induced in the hybrid nonwoven geotextiles and their notch-sensitive behaviour and the failure mechanisms are reported.

1. Introduction

Geotextiles have been successfully produced from synthetic or natural fibres depending upon their short- and long-term applications. For example, natural fibre based geotextiles are normally employed for short-term reinforcements and erosion-control applications whereas the synthetic fibres perform well for long-term functions of geotextiles. In general, synthetic and natural fibres offer their own advantages and disadvantages for geotextile applications. Specifically, natural fibres are environment friendly, biodegradable, less costly and exhibit high initial modulus. These characteristics of natural fibres have resulted in a range of geotextile applications namely, soil erosion control, vertical drains, road bases, river bank protection and slope stabilisation (Ahn et al., 2002; Datta, 2007; Datye and Gore, 1994; Lekha, 2004; Mitchell et al., 2003; Rawal and Anandjiwala, 2007; Rawal and Saraswat, 2011a,b; Saha et al., 2012; Subaida et al., 2009). The natural fibres that are employed for geotextile applications are generally plant fibres such as jute, flax, hemp, sisal, abaca, ramie, coir, etc. Particularly, jute fibres have shown a great potential for numerous geotextile applications including agriculture, civil engineering construction, drainage and embankment control (Ranganathan, 1994). However, these natural fibres have inherent variation in their physical and mechanical properties that have detrimental effect on various properties of nonwoven geotextiles (Rawal and Anandjiwala, 2007). In such cases, the natural fibre based geotextiles can encounter difficulties in conforming to the norms and the specifications of any geotextile application. This is one of the primary reasons that synthetic fibres have been dominant in the geotextile and other civil engineering applications.

According to Basu et al. (2009), adding a certain quantity of synthetic fibre/film can enhance the physical and mechanical characteristics of natural fibre based geotextiles. Moreover, there is a growing concern for the use and disposal of synthetic materials that has renewed interest in hybrid geotextiles consisting of synthetic and natural fibres in defined proportions. To the authors' knowledge, limited research work has been found in the literature for optimising the content of synthetic and natural fibres specifically in hybrid nonwovens for superior physical and mechanical properties. Therefore, the overall objective of the present work is to compare and analyse the physical and mechanical properties of hybrid needlepunched nonwoven geotextiles produced from jute and polypropylene fibres in defined proportions. Furthermore, two types of mechanical damage (i.e., a horizontal cut and a circular hole) were artificially induced in the hybrid nonwoven geotextiles and their notch-sensitive behaviour and the failure mechanisms are reported.

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Table 1
Physical properties of fibres used in the production of nonwoven geotextiles.

Type of fibre	Staple length (mm)	Linear density (dtex)	Diameter (μm)	Tenacity (N/tex)	Tensile strength (MPa)	Initial modulus (GPa)	Extension at break (%)
Jute	51	28.1	53.38	0.294	369	38.92	1.18
Polypropylene	60	6.6	25.24	0.415	548	1.30	30.00

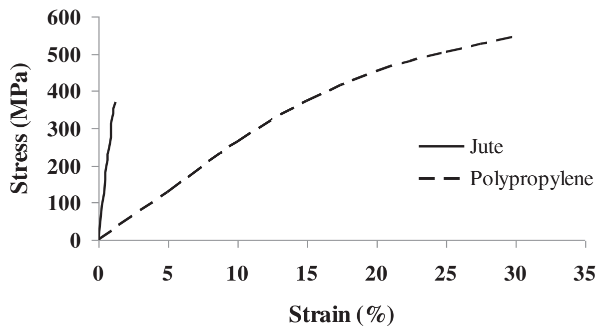

Fig. 1. Typical stress–strain curves of jute and polypropylene fibres.

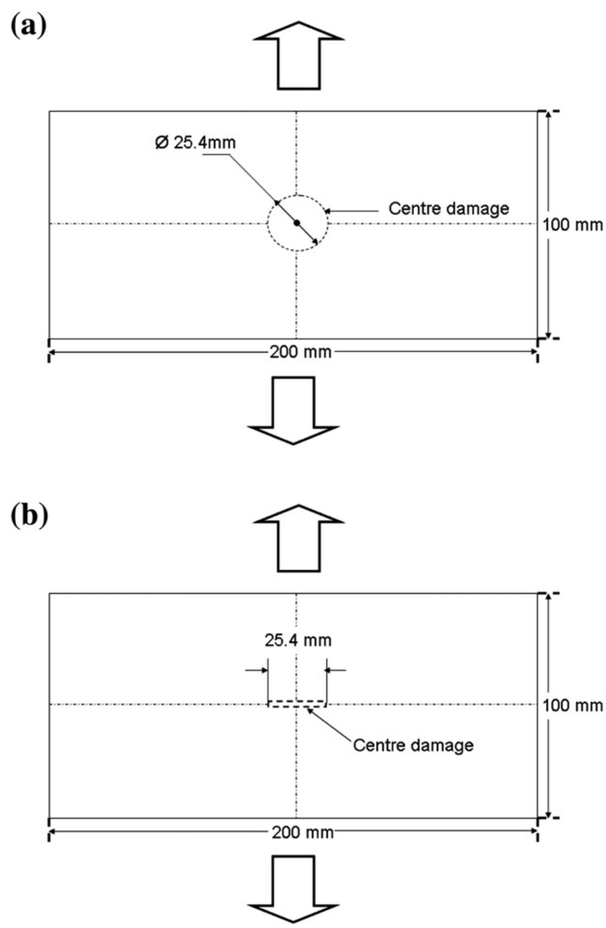

Fig. 2. Types of induced damages (a) circular hole (b) horizontal cut in hybrid Jute/PP nonwoven geotextiles.

2. Experimental

Tossa jute of grade BTC (Bangla Tossa C) and polypropylene (PP) staple fibres were mixed in defined weight proportions to fabricate needlepunched nonwoven geotextiles. The constituent fibre properties are given in Table 1 and the typical stress–strain curves of jute and polypropylene fibres are shown in Fig. 1.

2.1. Sample preparation

Four samples of hybrid needlepunched nonwoven geotextiles have been prepared in defined Jute/PP weight proportions, i.e., 00/100, 20/80, 40/60 and 60/40. These fibres were opened and blended by means of carding and subsequently, orientated to cross-machine direction using a cross-lapper to form cross-laid webs. These cross-laid webs were then subjected to the needlepunching process to fabricate hybrid nonwoven geotextiles of nominal mass per unit area of 400 g/m^2. It must be noted that the process parameters were kept constant during the fabrication of all the four geotextile samples.

2.2. Testing of needlepunched nonwoven geotextiles

The hybrid needlepunched nonwovens were tested for various physical and mechanical properties. Initially, the homogeneity of Jute/PP nonwoven geotextiles was verified using ASTM D629 for quantifying the proportion of polypropylene and jute fibres in the hybrid geotextiles. Here, the hybrid geotextiles were treated with 70% concentrated sulphuric acid for 25 min at a room temperature that dissolved the jute fibres. Subsequently, the remaining polypropylene fibres were washed with distilled water and neutralised with 2 wt.% sodium bicarbonate and again washed with distilled water before drying in oven at 100 °C for 90 min. Geotextile thickness was determined under pressures of 2, 20 and 200 kPa using mechanical thickness testing equipment according to EN 964-1 (1995). Here, the geotextiles were placed horizontally over a flat surface and a load was applied through a pressure foot of 56.4 mm diameter. Sample sizes of 80 mm × 80 mm were tested and an average of six readings was recorded. Subsequently, the porosity of geotextile was computed under abovementioned pressures using equations (1) and (2).

$$\eta = 1 - \frac{G}{T\rho} \tag{1}$$

and

$$\rho = \frac{\rho_1 \rho_2}{x\rho_2 + (1-x)\rho_1} \tag{2}$$

Table 2
Physical properties of Jute/PP hybrid needlepunched nonwoven geotextiles.

Samples ID	Measured fabric mass/unit area (g/m^2)	Thickness (mm)			Porosity (%)			Change in porosity (%)	
		2 kPa	20 kPa	200 kPa	2 kPa	20 kPa	200 kPa	2–20 kPa	2–200 kPa
00/100 Jute/PP	390 ± 10.07	4.12 ± 0.12	3.68 ± 0.04	1.62 ± 0.06	90	88	74	2.22	17.77
20/80 Jute/PP	394 ± 7.27	4.01 ± 0.12	3.37 ± 0.05	1.75 ± 0.12	90	88	77	2.22	14.44
40/60 Jute/PP	405 ± 6.68	3.85 ± 0.10	3.26 ± 0.10	1.80 ± 0.04	90	89	79	1.11	12.22
60/40 Jute/PP	410 ± 10.04	3.60 ± 0.13	3.08 ± 0.19	1.65 ± 0.21	90	89	79	1.11	12.22